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SeagrassNet Monitoring in the Great Bay Estuary, NH/ME Field Season 2019

Kalle Matso
University of New Hampshire

Trevor Mattera
University of New Hampshire

Fred Short
University of New Hampshire

David Burdick
University of New Hampshire

Lara Martin
University of New Hampshire

See next page for additional authors

Authors

Kalle Matso, Trevor Mattera, Fred Short, David Burdick, Lara Martin, Nicole Sarrette, Nick Anderson, Dante Torio, and Tom Gregory

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Dr. Kalle Matso[1], Trevor Mattera[1], Dr. Fred Short[2], Dr. David Burdick[2], Lara Martin[2], Nicole Sarrette[2], Nick Anderson[2], Dr Dante Torio[2], Tom Gregory[2]

[1] Piscataqua Region Estuaries Partnership (PREP); [2] UNH Jackson Estuarine Laboratory

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Introduction

SeagrassNet is a global monitoring program started in 2001 by Dr. Fred Short. Since Dr. Short's retirement, SeagrassNet is currently in the process of being transferred to the Smithsonian Institute. SeagrassNet is designed to scientifically detect and document seagrass habitat change (Short et al. 2015). Eelgrass (*Zostera marina* L.) forms a critical habitat in the Great Bay Estuary, and is valued not only for the functions it provides but also as indicator of water quality. Annual monitoring (3-4 times a year) of eelgrass in the Great Bay Estuary using SeagrassNet was conducted in Portsmouth Harbor between 2001 and 2009 (Short et al 2006b, Rivers and Short 2007). This site was discontinued after eelgrass failed to recover from grazing by Canada Geese in the winter of 2003. SeagrassNet monitoring in Great Bay started in 2007 (Short et al. 2009); that site is referred to as "NH 9.2, Great Bay." In July 2019, a new site was established in Portsmouth Harbor—approximately 1,000 meters from the previous site—and designated "NH 9.3, Fort Foster." Results from SeagrassNet 2019, conducted in Great Bay and at Fort Foster, are described in this report.

Sites

The two sites were established following the standard SeagrassNet protocol (Short et al. 2006a) used worldwide. Details are noted in "Methods" and further details and context can be found in the Quality Assurance Project Plan for the Great Bay Estuary (Matso and Short 2019). For SeagrassNet, a "site" consists of three permanent, parallel, 50 m transects (referred to as A, B and C). For all SeagrassNet sites, transect A is closest to shore and shallowest; C is furthest from shore and deepest (Figures 1 through 4). See figure captions for water depths at each transect.

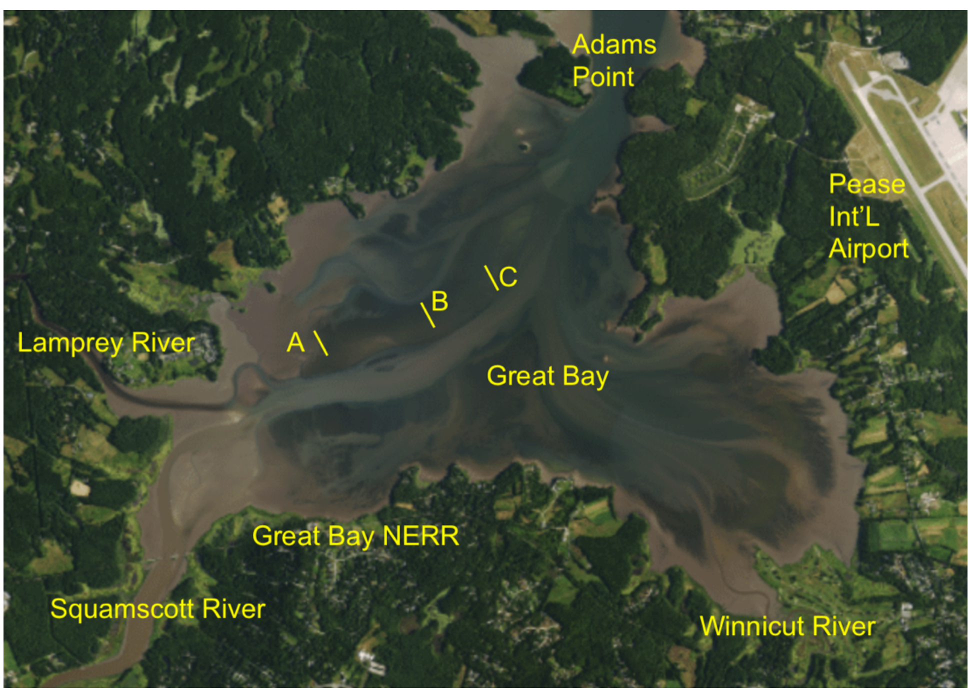

Figure 1. SeagrassNet monitoring site, NH 9.2, with Transects A, B and C in Great Bay, New Hampshire. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Lines showing transects are not to scale. Transect depth estimates (Mean Low Lower Water) are: A = 0 ft; B = 1 ft; C = 2 ft.

Figure 2. SeagrassNet monitoring transects, using GPS-identified points for each end and the midpoint of permanent Transects A, B, and C in Great Bay, New Hampshire. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale.

Figure 3. SeagrassNet monitoring site, NH 9.3, with Transects A, B, and C in Portsmouth Harbor, NH/ME, at Fort Foster. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale. Transect depth estimates (Mean Low Lower Water) are: A = 4 ft; B = 6 ft; C = 12 ft.

Figure 4. SeagrassNet monitoring transects, using GPS-identified points for each end and the midpoint of permanent Transects A, B, and C in Portsmouth Harbor, NH/ME, at Fort Foster. Baseline imagery taken in 2019 for eelgrass distribution monitoring and available via NH Coastal Viewer. Distances between transect points are not to scale.

<u>Sampling</u>

In 2019, SeagrassNet quadrats were sampled three times at Great Bay (April, July, and October). The specific dates were: April 18 – 20, August 2 – 3 and October 28 – 29. The Great Bay site was sampled by a team using snorkel at low tide. Quadrats are $0.25m^2$ and placed at specific random locations (Figure 5).

The newly established site, Fort Foster, was sampled twice: July 2019 and October 2019. The specific sampling dates were July 24 – 26 and October 20 – 21. All sampling was done by SCUBA. Fort Foster was sampled only twice, as compared with three times for Great Bay, due to limited resources for self-contained underwater breathing apparatus (SCUBA).

SeagrassNet sampling parameters for each quadrat include: photographic record; percent cover; canopy height; biomass (above and belowground combined); shoot density; and sexual reproduction (number of flowering shoots). Biomass assessments focus on the type of shoots (non-reproductive versus reproductive) that are dominant in the quadrat; this is almost always the non-reproductive shoots. Note that the biomass sampling procedure in the SeagrassNet Manual (Short et al. 2015) advises an alternative method for assessing biomass for "large seagrass species" like eelgrass. Instead of taking a core, the field team collects an individual shoot including at least 7 cm of rhizome approximately 0.5m landward of each quadrat. Then, shoot weight is determined in the lab and multiplied by density to obtain biomass.

The position of the quadrats (Figure 5) along each transect was assigned during the development of the SeagrassNet protocol using a random number generator and does not change, providing repeated measure assessment of specific parts of each eelgrass bed over time.

The SeagrassNet protocol includes other parameters that are not quadrat specific, but rather apply to the site or to particular transects at the site; these include temperature, salinity and light penetration. For light penetration, HOBO sensors (without wipers) from Onset (HOBO Pendant Temperature/Light 8K Data Logger; Model #UA-002-08) were deployed for at least two-weeks as part of each sampling event. The sensors for light also measure water temperature; salinity is measured with a separate sensor (HOBO Conductivity Logger, Model #U24-002-C.) For the light analysis, only the data between 10 a.m. and 2 p.m. are analyzed in order to avoid the effects of low sun angle on the light data. Values collected every 15 minutes during the 4-hour period are compared with land-based values in order to produce percent light penetration. These values are then used to produce a daily average.

In 2019, as part of a student thesis project, additional sensors that measured both temperature and salinity were deployed and left out continuously from April through October in Great Bay. These additional sensors were not deployed in Fort Foster due to limited time and equipment. Complete SeagrassNet protocols for this project are found in the project QAPP (Matso and Short 2019).

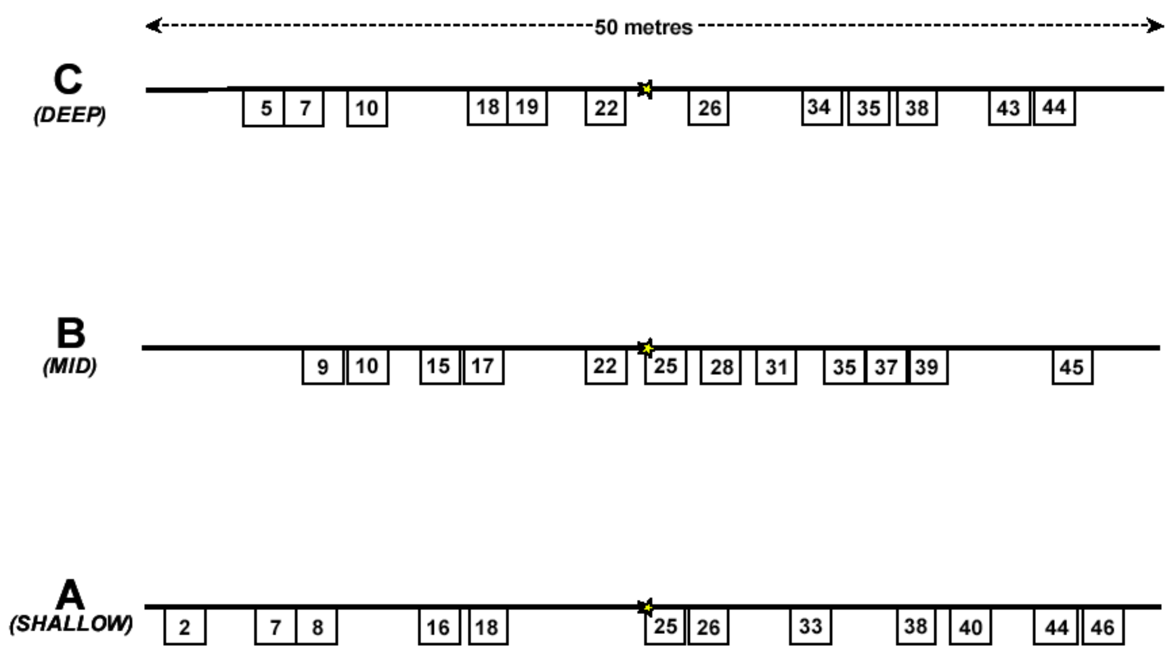

Figure 5. Location of the 12 SeagrassNet quadrats along the 50 m transects. Each square represents a quadrat. Numbers indicate the meter distance along each transect where the quadrats are positioned for sampling. The stars represent the midpoint of each transect.

We define 'Percent in situ surface light' as the amount of light reaching the plants compared to the amount of light at the water surface. This is calculated by dividing the amount of light underwater reaching the plants by the amount of light at the water surface. The light reaching the water surface is obtained via a Hobo sensor located at Jackson Estuarine Laboratory. The authors recognize that it would be better to have a separate and closer sensor for the land-based measurements for Fort Foster. We hope to include this in coming years.

Results

Note that the primary focus of this report is on 2019 results. Inter-year comparisons and more detailed discussions will be featured in other publications, such as future State of Our Estuaries reports. In addition, please note that wasting disease was not assessed in 2019 although it is part of the SeagrassNet protocol. "Evidence of grazing" was assessed but no evidence was seen at any of the sampling events.

Table 1: Mean values for SeagrassNet parameters. Standard deviation in parentheses. The median is given for reproductive shoots because of the skewed distribution of values.

	Great Bay Site			Fort Foster Site		
	Transect A	**Transect B**	**Transect C**	**Transect A**	**Transect B**	**Transect C**
Biomass (g/m2)						
April	0.03 (0.1)	1.5 (0.8)	7.1 (5.0)	Not sampled	Not sampled	Not sampled
July/August	0	39.4 (14.7)	62.7 (27.9)	40.3 (106.1)	182.1 (147.9)	188.8 (143.5)
October	0	6.6 (4.1)	10.4 (6.0)	68.4 (80.7)	161.1 (76.6)	Not sampled
Percent Cover						
April	0.08 (0.3)	9.4 (8.2)	21.1 (13.4)	Not sampled	Not sampled	Not sampled
July/August	0	59.3 (18.5)	51.7 (27.1)	15.2 (24.7)	33.8 (18.3)	50.0 (15.4)
October	0	61.3 (18.4)	97.5 (1.7)	24.9 (28.3)	49.0 (21.0)	Not sampled
Density (shts/m2)						
April	1 (3.3)	36.3 (21.3)	60.0 (30.2)	Not sampled	Not sampled	Not sampled
July/August	0	62.7 (20.0)	62.7 (23.1)	54.5 (79.6)	191.0 (129.8)	149.3 (51.7)
October	0	37.2 (10.3)	72.3 (19.7)	130.0 (142.7)	261.7 (124.3)	Not sampled
Canopy Ht (cm)						
April	5 (0)	12.7 (2.7)	17.2 (2.4)	Not sampled	Not sampled	Not sampled
July/August	0	70.2 (9.2)	84.2 (12.0)	44.6 (28.0)	98.1 (33.8)	126.3 (15.1)
October	0	59.5 (4.7)	88.0 (10.5)	46.7 (37.6)	115.9 (30.4)	Not sampled
Repro Shoots (#)						
April	0	0	0	Not sampled	Not sampled	Not sampled
July/August	0	5.5 (2.3)	2.0 (1.5)	0 (4.2)	2.5 (2.3)	2.0 (1.4)
October	0	0 (0.5)	0 (0.3)	0	0	Not sampled
Seaweed % Cov						
April	0 (1.4)	0.3 (0.5)	0.1 ((0.3)	Not sampled	Not sampled	Not sampled
July/August	0.4 (1.4)	6.5 (6.9)	6.7 (9.6)	24.1 (21.7)	24.2 (18.8)	18.3 (17.9)
October	0.4 (0.5)	11.4 (13.2)	1.9 (1.4)	11.9 (25.0)	7.9 (4.5)	Not sampled

Eelgrass Biomass

Biomass refers to the weight of eelgrass plant tissue per square meter, e.g., grams/m^2. In this case, biomass includes a combined measure of both belowground and aboveground plant tissue. Biomass is considered very dependent on light and is therefore an important metric (Krause-Jensen et al. 2004).

At the Great Bay site there was 0.03 g/m^2 of eelgrass at Transect A (the shallowest transect) in April, and there was no eelgrass at either of the later sampling events in July/August and October (Table 1; Figure 6). At Transects B and C, peak biomass was seen at the July/August sampling event, where Transect B had 39.4 g/m^2 and Transect C had 62.7 g/m^2.

At the Fort Foster site, Transect C was only sampled in July due to difficulties with SCUBA logistics. In contrast with Great Bay, only one of the Fort Foster transects (Transect B with 182.1 g/m^2) peaked in eelgrass biomass in July/August; Transect A peaked in October with 68.4 g/m^2, rather than in July (Table 1; Figure 7). Transect C was only sampled in July/August and had 188.8 g/m^2.

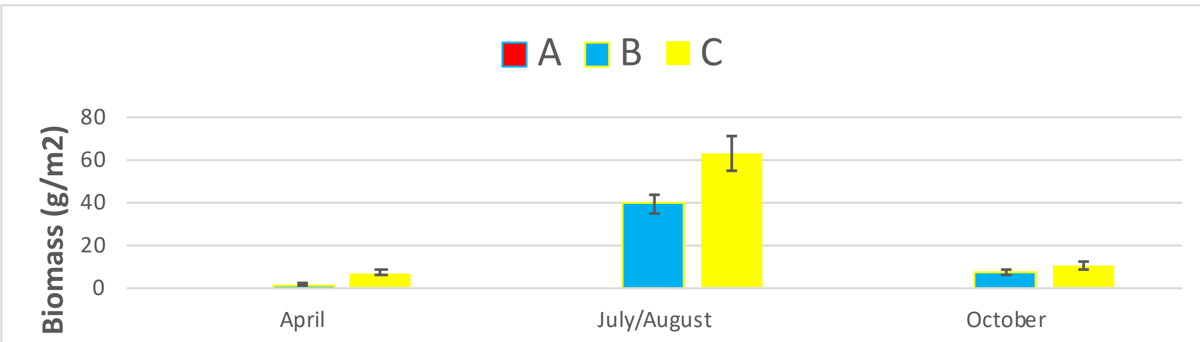

Figure 6. Eelgrass biomass at SeagrassNet site NH9.2 (Great Bay), Transects A, B, and C for 2019. Error bars indicate Standard Error.

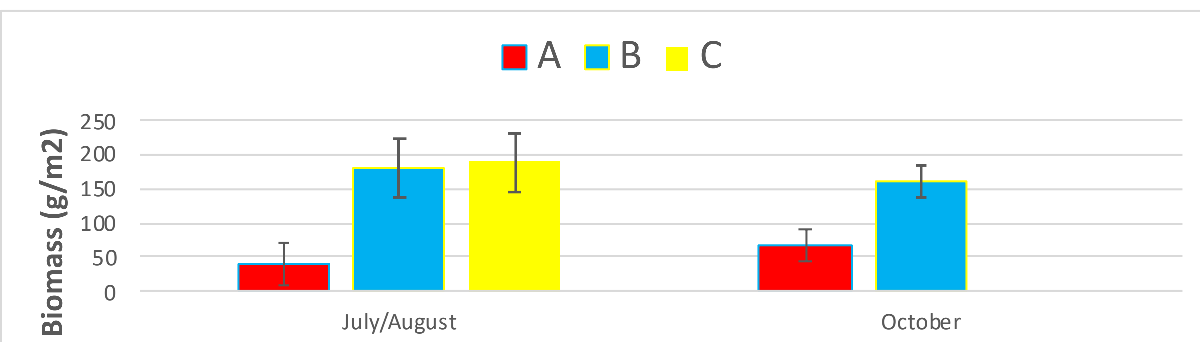

Figure 7. Eelgrass biomass at SeagrassNet site NH9.3 (Fort Foster), Transects A, B, and C for 2019. Error bars indicate Standard Error.

Eelgrass Percent Cover

Percent cover is a visual measure, looking straight down, of how much of the substrata within the quadrat is covered by seagrass on a scale of 0 – 100%. Each person on the team is trained using a percent cover guide, a standard scientific field technique for vegetation measurements.

For the Great Bay site, Transect A had a mean percent cover 0.08% in April. In July/August and October, there was no grass at all at Transect A (Table 1; Figure 8.) Transect B had its highest percent cover (61.3%) in October, only slightly above the amount in July, which was 59.3%. Transect C, the deepest transect, had its highest percent cover (97.5%) in October. In July, Transect C had 62.7% cover.

At Fort Foster, Transects A and B showed slight increases from the July/August sampling to the October sampling, peaking at 24.9% and 49.0%, respectively (Table 1; Figure 9). When Transect C was sampled in July, the mean percent cover 50%, the highest of the three transects.

Eelgrass Shoot Density

Shoot density is the number of shoots in a given space, e.g., square meters. Density is considered more sensitive to changes in light than percent cover, which can also be impacted by leaf length (Krause-Jensen et al. 2004). When using density as an indicator of eelgrass health, it is important to also consider canopy height, since eelgrass can grow more densely but with much shorter shoots, depending on light. In that case, without considering other parameters, one could misinterpret a change in density for a change in overall biomass.

For Great Bay, Transect A, as noted in the "Percent Cover" section, had negligible shoots throughout the year. Transect B had a maximum shoot density of 62.7 shoots/m^2 (Table 1; Figure 8), and Transect C had a maximum shoot density of 72.3 shoots/m^2. Note that Transect B's peak was during the July/August event while Transect C peaked in October.

At Fort Foster, similar to percent cover at that site, Transects A and B showed increases from the July/August sampling to the October sampling. Once again, Transect B had the highest values, peaking at 261.7 shoots/ m^2 in October (Table 1; Figure 9). Transect A peaked in October with 130.0 shoots/m^2. Transect C was only sampled in July/August and had 149.3 shoots/m^2.

Eelgrass Canopy Height

Canopy height represents the mean length of leaves less than the tallest 20%. Canopy height is a useful metric, especially when combined with other indicators (e.g., density and percent cover) to achieve a proxy for biomass. (Biomass can be a very time-consuming metric to achieve. If you can establish a relationship between biomass and percent cover, density and canopy height, one can use a model approach to predicting biomass across the estuary (Neckles et al. 2012).

At Great Bay, Transect A, as noted above, had very little eelgrass, so canopy height was neglible throughout the year. For Transect B, the canopy height maximum was 70.2 cm in JulyAugust, and decreased to 59.5 cm in October (Table 1; Figure 8). In contrast, Transect C peaked in October at 88.0 cm, up from 84.2 cm in July/August.

At Fort Foster, Transects A and B showed less of a difference between the July/August and October sampling. In JulyAugust, the deepest transects had the longest leaves (Table 1; Figure 9). Transect C had a mean canopy height of 126.3 cm, while Transect B ranged between 98.1 and 115.9 cm from July/August to October. Transect A had the shortest plants, with average canopy height at 44.6 cm in July/August and 46.7 cm for October.

Eelgrass Flowering

Counting the number of flowering shoots per square meter helps to assess eelgrass sexual reproduction, which can play a critical role in eelgrass resilience, via the plant's response to stress (Jarvis et al. 2014). Below, median number of reproductive shoots are given, rather than the mean, due to the skewed distribution of the values.

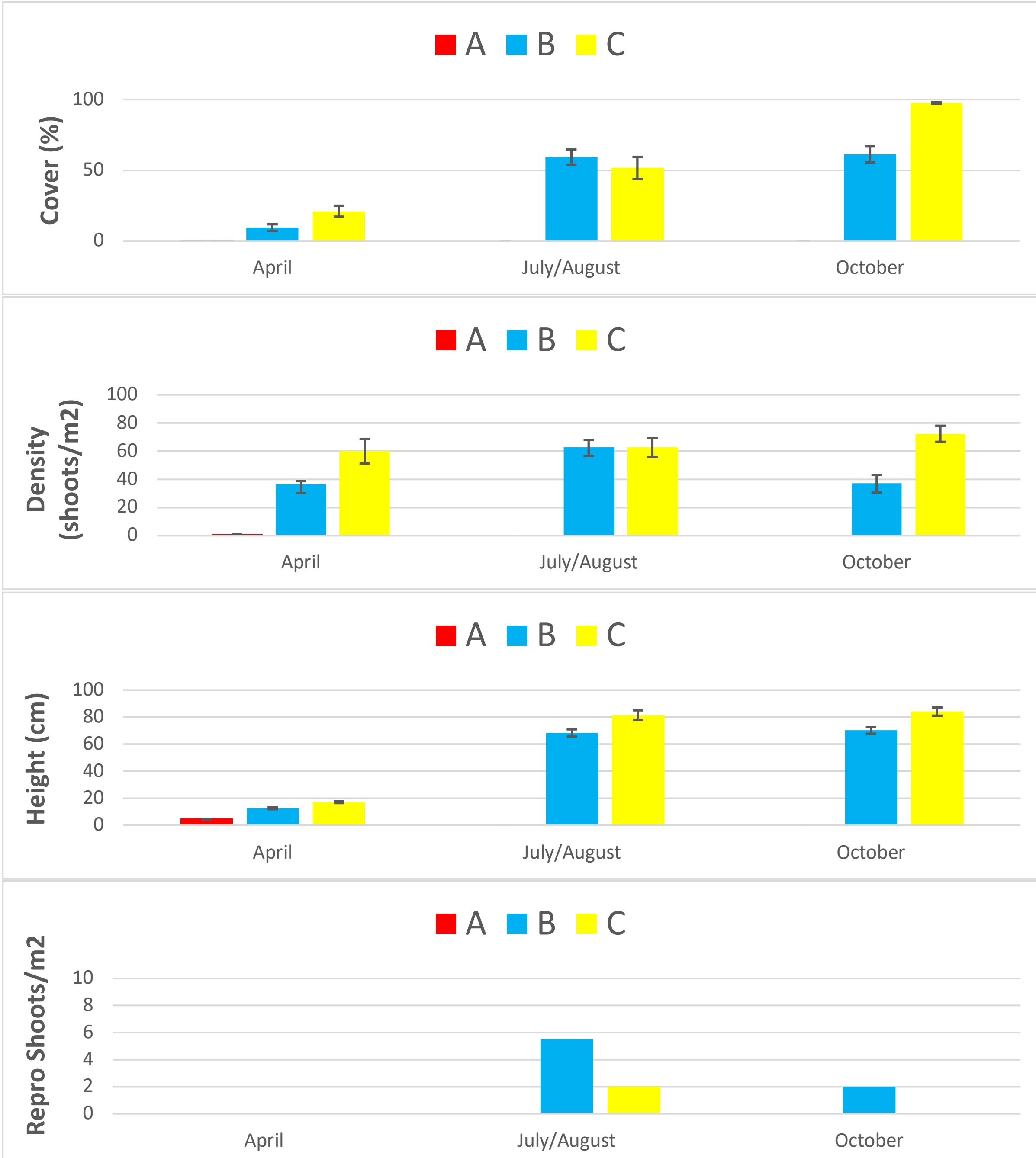

Figure 8. Eelgrass percent cover, shoot density, canopy height, and number of reproductive shoots at SeagrassNet site NH9.2, Transects A, B, and C in Great Bay for April 2019 – October 2019. All values are averages except for number of reproductive shoots, which are medians. Error bars indicate Standard Error.

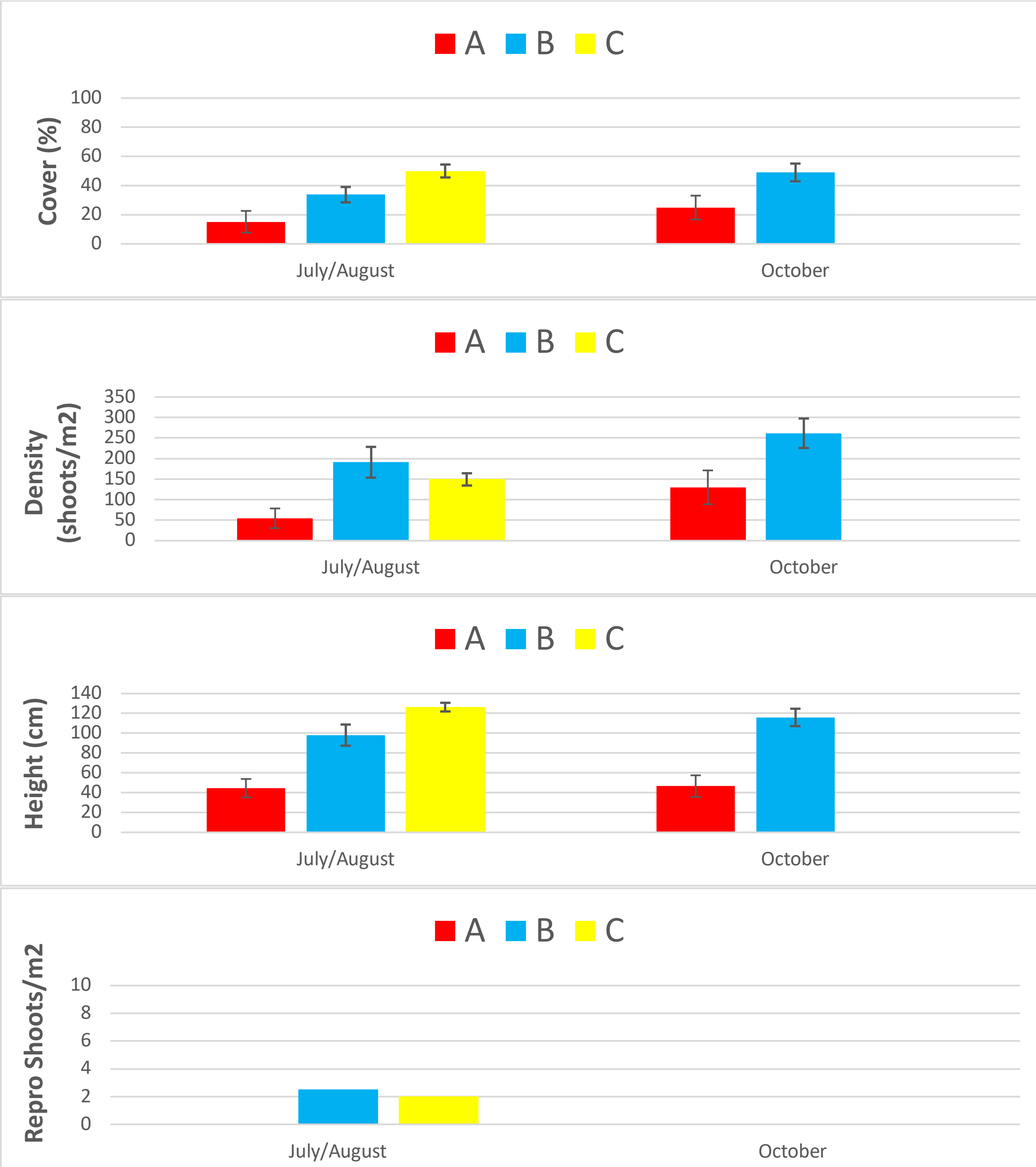

Figure 9. Eelgrass percent cover, shoot density, canopy height, and number of reproductive shoots at SeagrassNet site NH9.3, Transects A, B, and C at Fort Foster for July and October 2019. No sampling was done at Transect C for October 2019. All values are averages except for number of reproductive shoots, which are medians. Error bars indicate Standard Error.

In Great Bay, the most reproductive shoots occurred at the July/August sampling, which is when biomass was highest. Transect B had the most reproductive shoots with a median of 5.5 per quadrat, while Transect C had a median of 2.0 per quadrat (Table 1; Figure 8).

At Fort Foster, reproductive shoots were only counted in July/August. Once again, Transect B had the highest median for reproductive shoots per quadrat at 2.5 (Table 1; Figure 9). Transect C had a median of 2.0 per quadrat and Transect A had a median value of zero reproductive shoots per quadrat.

Percent Cover of Seaweeds at the SeagrassNet Transects

While many factors impact seaweed abundance, it is well established that changes in subtidal seaweed biomass and species composition can be a reflection of eutrophication status and, furthermore, that relatively well-flushed estuaries are more likely to see eelgrass degradation from seaweeds than from plankton (Valiela et al. 1997; van den Heuvel et al. 2019). For more on seaweeds in the Great Bay Estuary, including biomass and listing of different seaweed species, see the 2019 seaweed report at: https://scholars.unh.edu/prep/442/

In the Great Bay, seaweed cover stayed below 1% at Transect A (Table 1; Figure 10) over the course of the 2019 growing season. At Transect B and C, seaweed cover went from less than 1% in April to 6.5 and 6.7%, respectively, in July/August and October. Transect C peaked in July/August but Transect B increased to 11.4% in October.

At Fort Foster, seaweed percent cover at Fort Foster was higher in July/August than it was in October. Transects A and B had very similar July measurements: 24.1 and 24.2, respectively (Table 1; Figure 11). Transect C had 18.3% at the one sampling event in July/August.

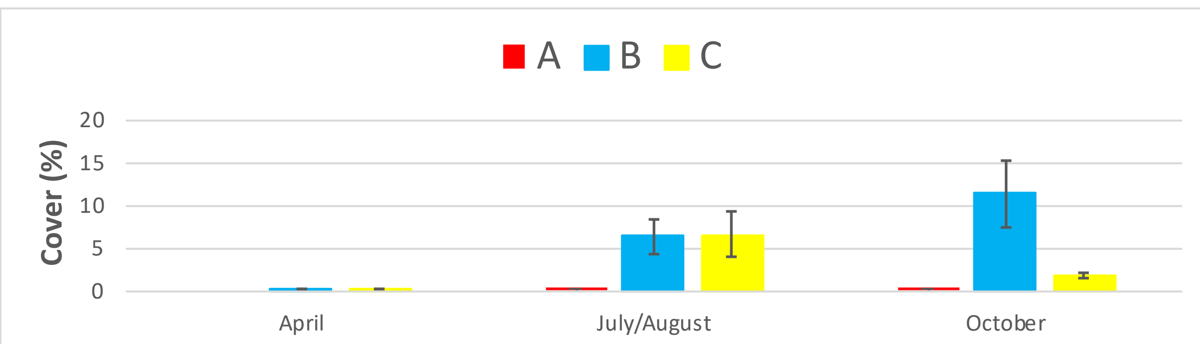

Figure 10. Seaweed percent cover at SeagrassNet site NH9.2 (Great Bay), Transects A, B, and C for 2019. Error bards indicate Standard Error.

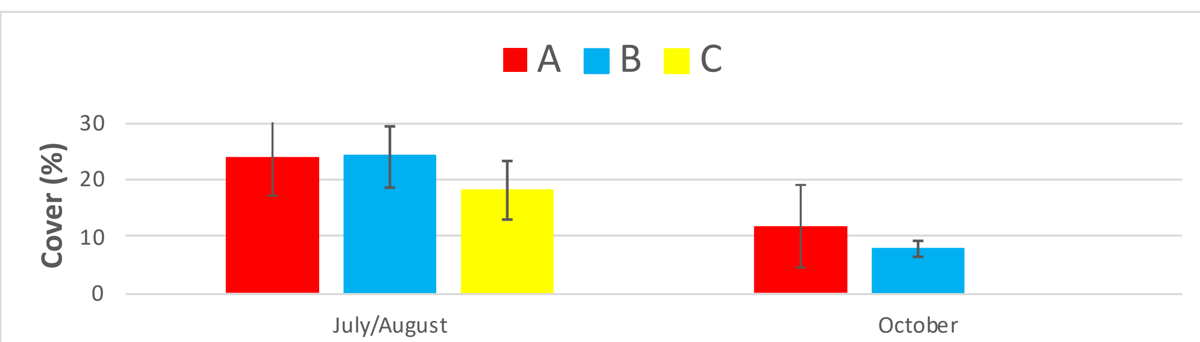

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Figure 11. Seaweed percent cover at SeagrassNet site NH9.3 (Fort Foster), Transects A, B, and C for 2019. Transect C was not sampled in 2019. Error bards indicate Standard Error. (No sampling occurred at Transect C in October.)

Temperature

Eelgrass can tolerate wide ranges for both temperature and salinity but studies indicate that optimal levels are narrower; Lee et al. (2007) report an optimal range of 13° to 24° C. Warmer temperatures than 24° can be associated with factors that degrade eelgrass (Burdick et al. 1993; Kaldy 2014). In the Great Bay, especially at the shallowest transect (A), summer temperatures in excess of 25° have been observed; temperatures this high can result in eelgrass mortality due to increased metabolic demands, which in turn requires higher water clarity.

In Great Bay, between mid-April and mid-August, the temperature ranged from below 10° to 30°; temperatures over 30° could be due to the sensor being out of water during extreme low tides (Figure 12). Transect A, the shallowest transect where plants are frequently exposed at low tide, had the greatest extremes with temperatures frequently between 25° and 30° throughout July and early August. Transect B, the medium-depth transect, also saw frequent excursions above 25°, though not as often as Transect A, and lower temperatures over all. Even at Transect C, temperatures rose above 25° on several occasions in late July. Between mid-April and Mid-June, temperatures were almost 100% below 25°.

At Fort Foster, data were available between July 25 and August 30 (Figure 13). In that period, the temperature ranged from almost 11.3° to 21°. In general, the temperature difference between the three transects, which are much closer together than the Great Bay transects, was almost always less than 1 C. The greatest differences were between Transect A and Transect C and amounted to less than 3°, but this was quite rare.

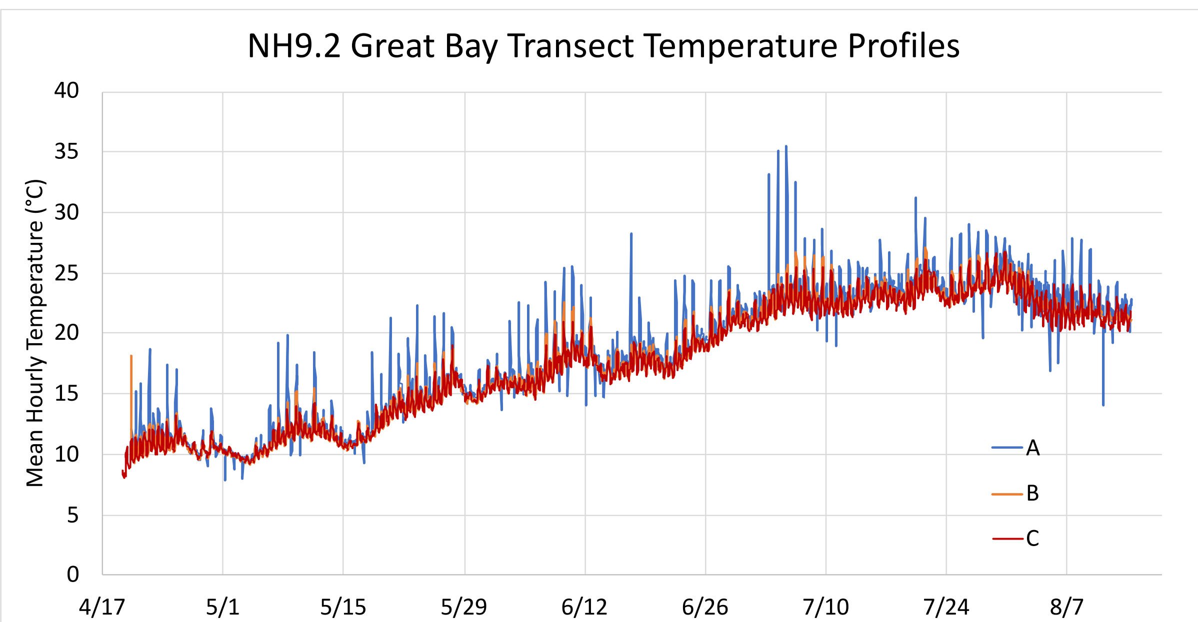

Figure 12: Temperature (hourly means) data from HOBO sensors for each of the three transects at site 9.2, Great Bay, from April 19, 2019 to August 14, 2019. Note temperatures over 30° could be due to the sensor being out of water during extreme low tides.

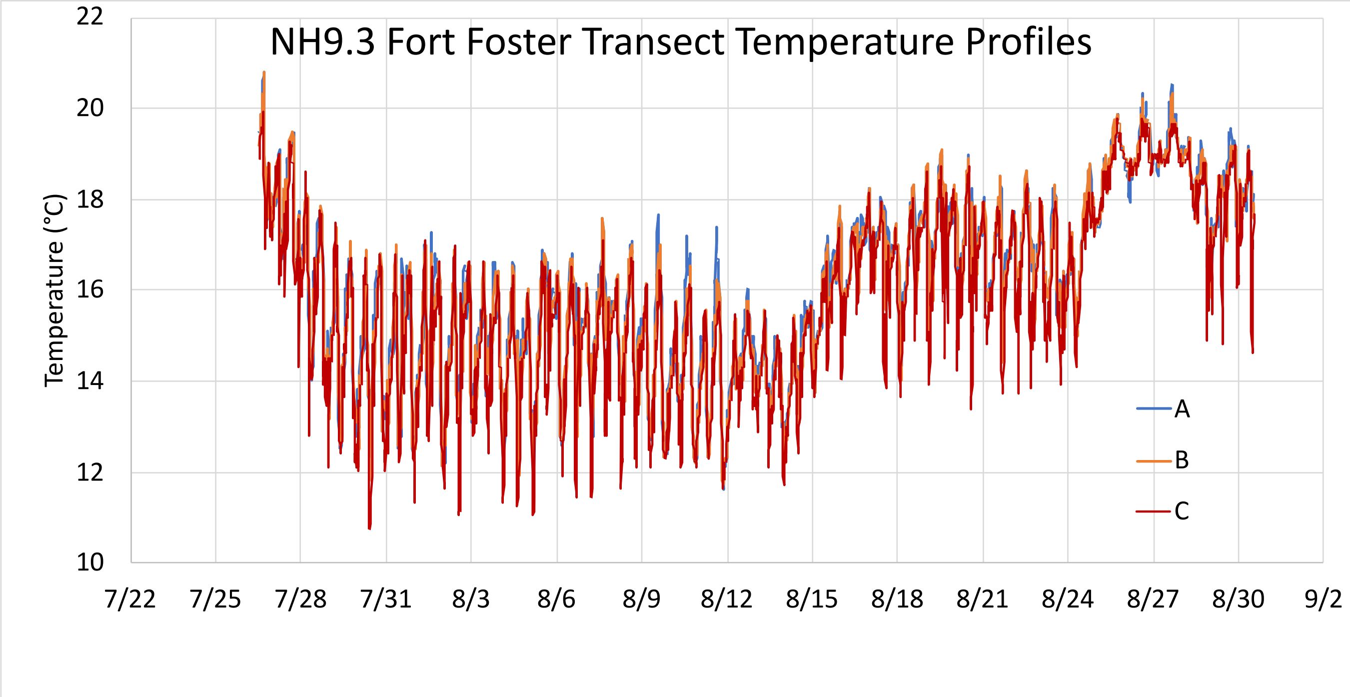

Figure 13: Temperature data (every 15 minutes) from HOBO sensors for each of the three transects at site 9.3, Fort Foster, July 26, 2019 to August 30, 2019. Note that the vertical access starts at 10° C.

Salinity

Eelgrass can tolerate (for limited times) virtually all salinities from 0 to 35 ppt. In general, however, higher salinity is beneficial to eelgrass, with salinities below 15 ppt negatively affecting eelgrass health indiators (Nejrup and Pederson 2008).

At Great Bay, the salinity varied greatly by the transect (Figure 14), according to water depth and also proximity to the mouth of the Lamprey River as well as the main channel in Great Bay (Figures 1 and 2). Transect A, shallowest and closest to freshwater inputs, regularly fluctuated between nearly 0 and 20 ppt. Transect B varied between 18 ppt and values in the low 20s during the summer months; in spring, salinity levels decreased below 10 ppt for a short period of time. Transect C saw greater variation in salinity levels than Transect B but less than Transect A. During storms, salinity levels could range between 7 and 21 ppt, but for most of the period between late June and mid-August salinity remained between 21 and 23 ppt.

At Fort Foster, salinity values from the HOBO are not reported due to a malfunction with the sensor. At the UNH Coastal Marine Laboratory, across the harbor from the monitoring site, salinities over the time period ranged between 30 and 33 ppt. This is expected since this site is adjacent to the Atlantic Ocean and much less susceptible to variations in salinity caused by inputs from freshwater tributaries.

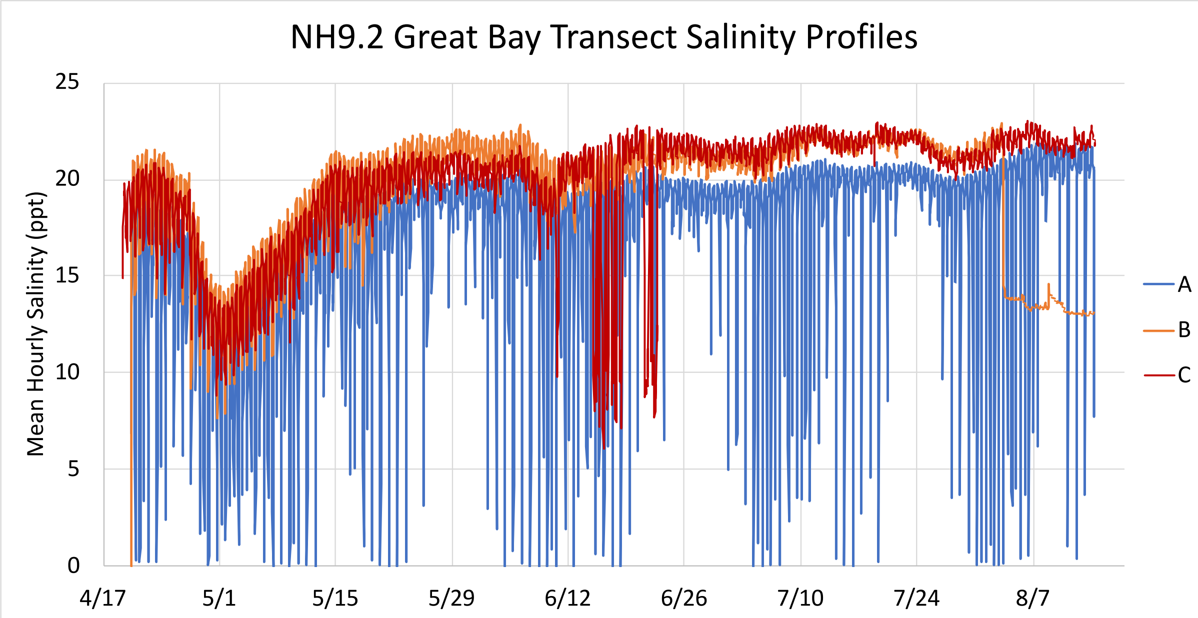

Figure 14: Hourly salinity data from HOBO sensors for each of the three transects at site 9.2, Great Bay, from April 19, 2019 to August 14, 2019.

Light

Seagrasses require more light than other marine primary producers because of their need to support growth and respiration of belowground structures (roots and rhizomes), which exist in an environment of low (if any) oxygen levels (Lefcheck et al. 2017). Therefore, light availability is often but not always the most important factor governing eelgrass growth rates (Ochieng et al. 2010). Previously, 11% in situ Surface Irradiation (SI)—the amount of light reaching the plants compared to the amount of light at the surface—was noted as the minimum threshold for eelgrass survival; however, subsequent research (e.g., Short et al. 1995; Ocheing et al. 2010) indicate that long-term eelgrass health can be negatively impacted when SI levels are consistently below 34%. Kenworthy et al. (2014) note that light requirements Massachusetts study areas varied from 9.5% to 29.7%, but that the central tendency was between 15% and 22%. Moreover, this study agreed with previous studies noting that light requirements tend to increase in areas with poorer water clarity and higher levels of organic matter.

Here, we focus on light results for the July/August timeframe. Additionally, for Great Bay, we focus on Transect C, which is the deepest transect. At Great Bay, Transect C, the highest mean percent light values were between 35 and 40% (Figure 15). As expected, these values occurred on those days when the tide height was lowest; lower tides result in less difference between the surface versus underwater levels. Other differences over the two-week period are associated with wind and precipitation events, which were verified using 2019 weather data.

At Fort Foster, percent light levels were lower overall than at Great Bay, most likely due to the plants growing in much deeper water (see Discussion below). The highest mean levels were between 15 and 25% (Figures 16, 17, and 18). Transect A and B had the highest percent light values at Fort Foster, which is expected since they are in shallower water. Note that the difference between A and B is relatively slight (Figures 16 and 17), but the difference between B and C is more significant. This most likely reflects differences in water depth.

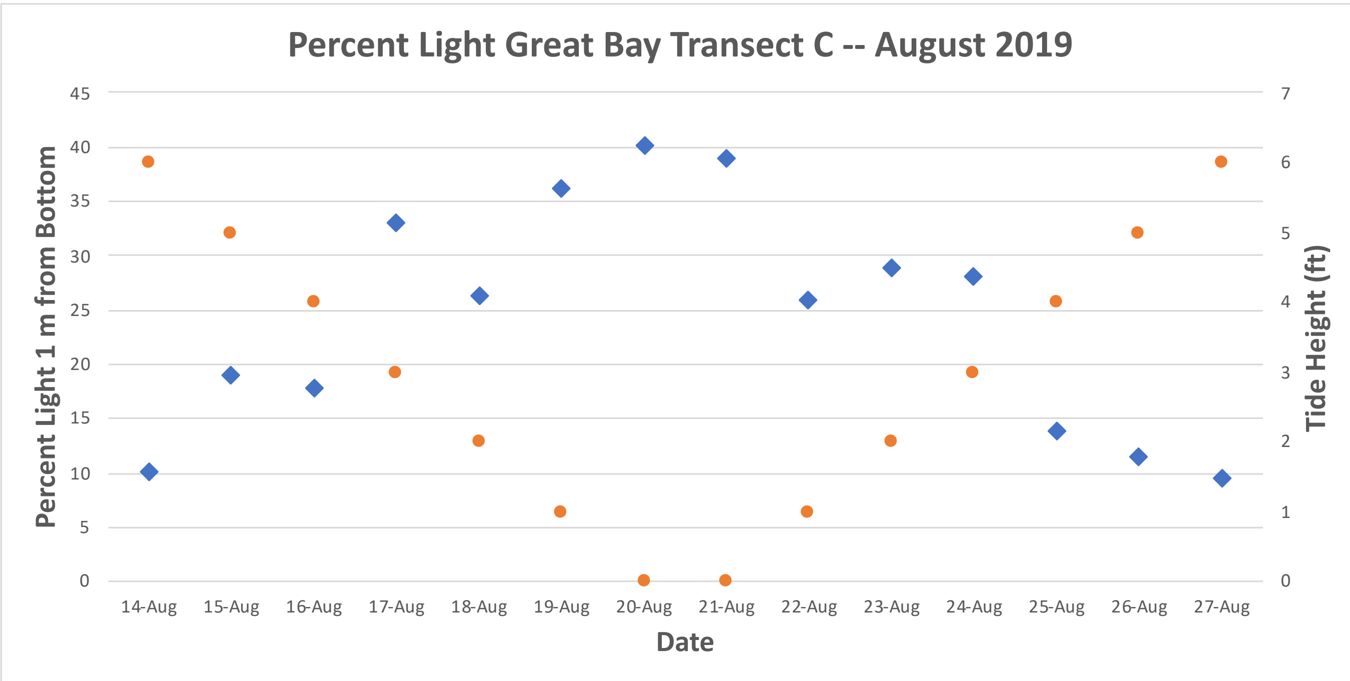

Figure 15: Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect C from the Great Bay site, August 14, 2019 to August 27, 2019. Values represent means from values taken by the HOBO sensor every 15 minutes, between 10 a.m. and 2 p.m. Tide height at noon in feet (orange circles) is plotted on the secondary axis. Only data for Transect C are plotted since Transects A and B experience less than 1 m depth at low tide.

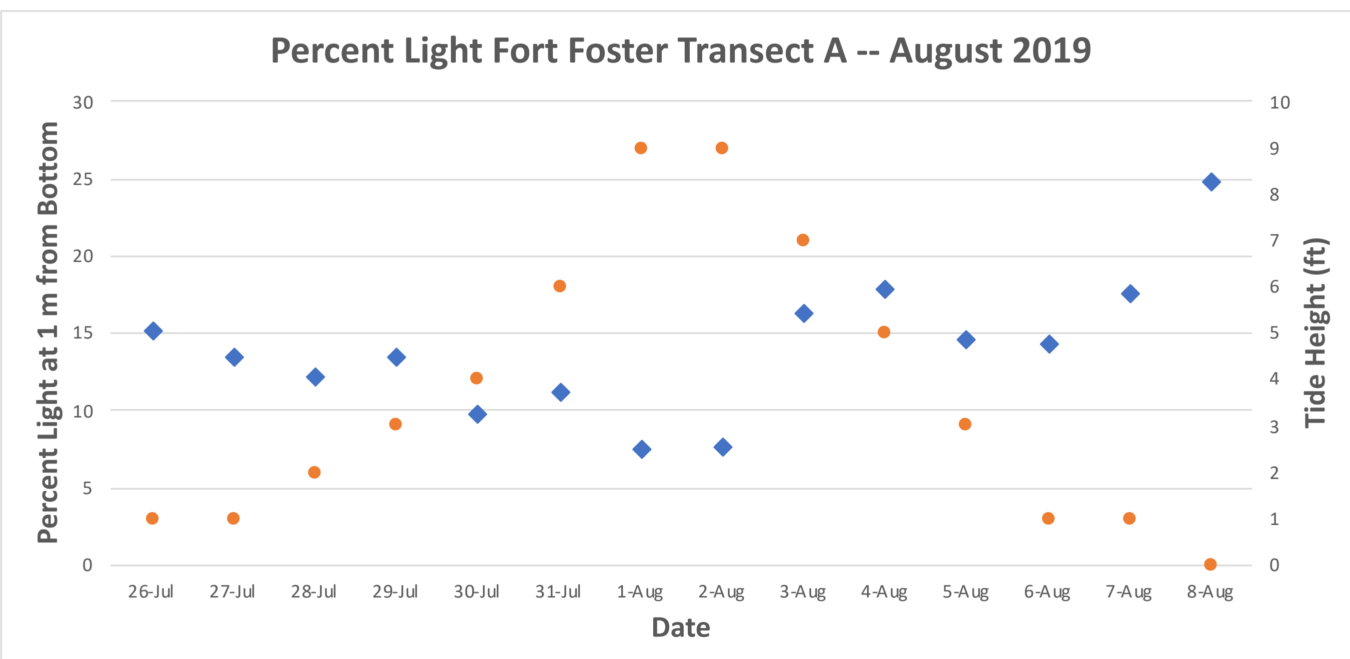

Figure 16: Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect A from the Fort Foster site, July 26, 2019 to August 8, 2019. Values represent means from values taken by the HOBO sensor every 15 minutes, between 10 a.m. and 2 p.m. Tide height at noon in feet (orange circles) is plotted on the secondary axis.

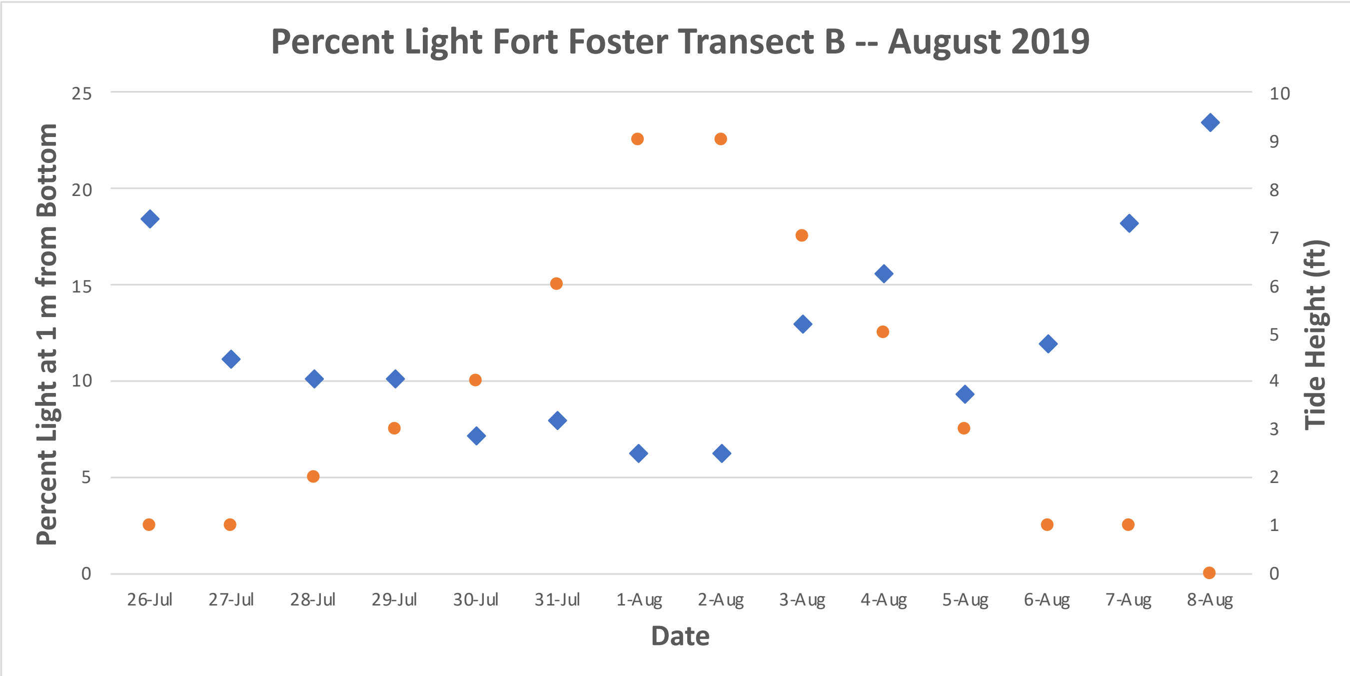

Figure 17: Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect B from the Fort Foster site, July 26, 2019 to August 8, 2019. Values represent means from values taken by the HOBO sensor every 15 minutes, between 10 a.m. and 2 p.m. Tide height at noon in feet (orange circles) is plotted on the secondary axis.

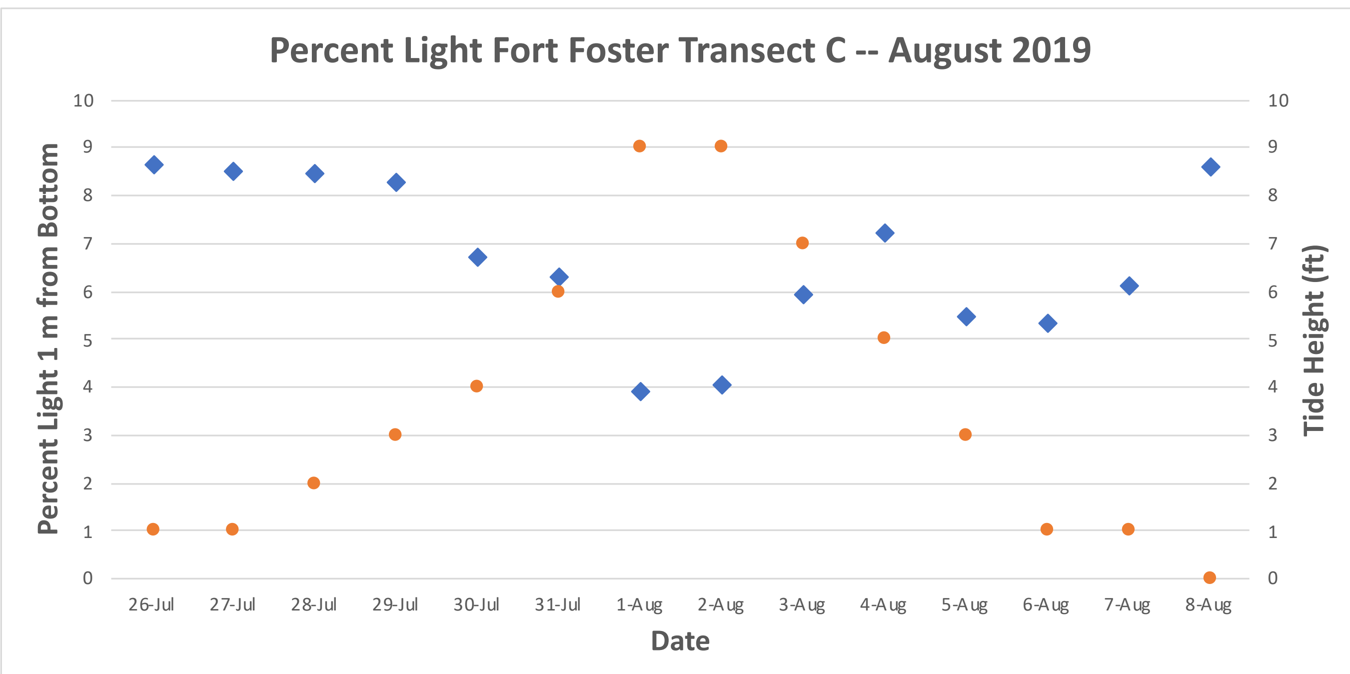

Figure 18: Mean values (blue diamonds) of percent light at 1 m from the bottom at Transect C from the Fort Foster site, July 26, 2019 to August 8, 2019. Values represent means from values taken by the HOBO sensor every 15 minutes, between 10 a.m. and 2 p.m. Tide height at noon in feet (orange circles) is plotted on the secondary axis.

Discussion

In 2019, for the areas where the SeagrassNet sites are located (west portion of Great Bay and the Maine side of Portsmouth Harbor), eelgrass abundance remains lower than levels from the 1980s. Short et al. (1993) report 1987-88 biomass levels in Great Bay (near Transect C) of 263 g/m^2. In 2019, in contrast, peak biomass levels in Great Bay were just over 50 g/m^2. The same report notes biomass levels at Fishing Island in Portsmouth Harbor (near the Fort Foster SeagrassNet site) of 506 g/m^2. In 2019, in contrast, peak biomass levels at Fort Foster were 180 g/m^2 (Figures 6 and 7). Density levels in 1987 for Fishing Island (near the Fort Foster monitoring site) were over 800 shoots/m^2 (Short et al. 1993), compared with a peak of 170 shoot/m^2 for Fort Foster in 2019 (Figure 9). Similarly, in 1988, eelgrass density in Great Bay near Transect C was 427 shoots/m^2 (Short et al. 1993) compared with approximately 50 shoots/m^2 in 2019.

Results from SeagrassNet in 2019 show contrasting conditions, both between the two sites (Great Bay and Fort Foster) overall, as well as between the Great Bay transects. The difference in conditions at the three Great Bay transects are much greater than at the Fort Foster transects, which are much closer together and are more similar in terms of depth profile. It is important to note that Great Bay's Transect A is completely exposed at low tide, making the eelgrass there very susceptible to wind and wave effects as well as impacts from ice, warm water, and dessication.

Overall, these results emphasize the more stressful conditions of the Great Bay eelgrass, which experience greater fluctuations in light, temperature, and salinity (Figures 12 - 18) than the eelgrass at Fort Foster. Also, results show that temperature and salinity levels in Great Bay are frequently outside optimal ranges for eelgrass: below 15 ppt for salinity and above 25° for temperature. In contrast, conditions at Fort Foster during the sampling period remained above 30 ppt and well below 25°.

With regard to light, according to data for Transect C at Great Bay over the sampled two-week period, eelgrass plants experienced conditions both below and above the 15%-22% range indicated in the Kenworthy et al. (2014) study (Figure 15). The eelgrass at Fort Foster experienced peak mean light levels of 25% (Transect A; Figure 16). At the deepest Transect (C), peak mean light levels were below 10% (Figure 17). This may seem surprising given the clearer water in Portsmouth Harbor (see photographs in Appendix 2). Several points are important in interpreting these data. First, the metric being discussed is percent light, not light attenuation (Kd). Light attenuation tends to increase as one moves up river, so Great Bay would have more light attenuation than Portsmouth Harbor. Percent light, on the other hand, represents the proportion of light from the surface that makes it to the eelgrass beds. Therefore, the depth of the eelgrass may have a significant impact, and the Fort Foster eelgrass beds are in much deeper water than the Great Bay eelgrass meadows. For example, at low tide at Transect C in Great Bay, the water depth can be as low as 1.5 ft. At Fort Foster's Transect C, the lowest water is closer to 12 ft. Also, these results are in agreement with the Kenworthy et al. (2014) study's conclusions: namely, that eelgrass growing in coarser sediment with less organic content will have lower light requirements.

The Great Bay eelgrass had a higher percent light but lower biomass and density than their counterparts at Fort Foster, highlighting the complexity of the light regime in this estuary. As noted above, finer sediments and higher organic matter in Great Bay could be increasing the light requirements for these plants (Kenworthy et al. 2014), which could have a higher photosynthesis requirement to aerate the belowground biomass. In addition, it is possible that the more extreme fluctuations in salinity and temperature in Great Bay could be impacting density and biomass. In addition, the eelgrass at Fort Foster is constantly submerged unlike the Great Bay eelgrass; even at the deepest Great Bay transect, the leaves can be lying flat on the surface of the water at low tide, which can create a constraint on the growth of the eelgrass.

Note also that Great Bay and Fort Foster were not sampled for light at the same time period, so some of the difference could be a reflection of the difference in wind and rain during the respective sampling times. Historical weather data confirms that there were slightly more windy and rainy days during the sampling period for Fort Foster. In addition, as noted earlier, there could be issues related to using a land-based reference for Fort Foster that is 8.5 miles away, versus only 1.8 miles away for the Great Bay transects, but with 16 measurements averaged for each day and two weeks of measurements, it is unlikely.

Although the results show that Great Bay has less seaweed than Fort Foster in terms of percent cover (Figures 10 and 11), the seaweed at Great Bay is often higher up in the canopy and seems to take up more space in three dimensions, since there is far less water when compared with Fort Foster. (Keep in mind that percent cover assessments are done in two dimensions, from the “bird’s eye” view, looking down.) Therefore, it’s possible that seaweeds are having a greater impact on eelgrass in Great Bay than they are at Fort Foster. In the estuaries of the Southern Gulf of St. Lawrence, van den Heuvel et al. (2019) demonstrate that seaweed not only negatively impacts eelgrass, but its influence is not necessarily captured in light measurements (as is phytoplankton), because seaweed blocks more light than phytoplankton, but vary much more over space and time. In Great Bay, seaweeds may be adding another stressor to already existing cumulative effects from salinity fluctuations, water clarity fluctuations, and sediment conditions.

More in-depth inter-year comparisons for eelgrass, seaweed, temperature, salinity, and light will be forthcoming in other PREP reports, such as the State of Our Estuaries Report.

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Appendix 1

Eelgrass data for biomass, percent cover, shoot density, canopy height and reproductive shoots at SeagrassNet site NH9.2, Transects A, B, and C in Great Bay for April 2019 – October 2019.

Location	Transect	Quadrat #	Date	Biomass	Eelgrass % Cover	Shoot Density (#/m^2)	Canopy Height (cm)	ReproShoot (#/0.25m^2)
Great Bay	A	1	4/20/19	0.0	0	0		0
Great Bay	A	2	4/20/19	0.0	0	0		0
Great Bay	A	3	4/20/19	0.0	0	0		0
Great Bay	A	4	4/20/19	0.0	0	0		0
Great Bay	A	5	4/20/19	0.0	0	0		0
Great Bay	A	6	4/20/19	0.0	0	0		0
Great Bay	A	7	4/20/19	0.0	0	0		0
Great Bay	A	8	4/20/19	0.0	0	0		0
Great Bay	A	9	4/20/19	0.0	0	0		0
Great Bay	A	10	4/20/19	0.0	0	0		0
Great Bay	A	11	4/20/19	0.4	1	12	5	0
Great Bay	A	12	4/20/19	0.0	0	0		0
Great Bay	B	1	4/18/19	1.9	15	52	17	0
Great Bay	B	2	4/18/19	0.8	5	20	13	0
Great Bay	B	3	4/18/19	2.1	15	64	15	0
Great Bay	B	4	4/18/19	0.8	8	28	15	0
Great Bay	B	5	4/18/19	0.7	5	24	15	0
Great Bay	B	6	4/18/19	0.5	1	8	10	0
Great Bay	B	7	4/18/19	2.6	3	20	8	0
Great Bay	B	8	4/18/19	1.8	15	44	13	0
Great Bay	B	9	4/18/19	0.9	3	24	11	0
Great Bay	B	10	4/18/19	0.8	8	48	10	0
Great Bay	B	11	4/18/19	1.8	5	24	11	0
Great Bay	B	12	4/18/19	3.1	30	80	14	0
Great Bay	C	1	4/19/19	6.3	35	56	19	0
Great Bay	C	2	4/19/19	3.0	10	24	13	0
Great Bay	C	3	4/19/19	4.3	15	52	18	0
Great Bay	C	4	4/19/19	9.6	30	72	14	0
Great Bay	C	5	4/19/19	9.5	40	120	18	0
Great Bay	C	6	4/19/19	4.5	5	32	14	0
Great Bay	C	7	4/19/19	3.0	10	48	16	0
Great Bay	C	8	4/19/19	4.5	15	48	19	0
Great Bay	C	9	4/19/19	2.1	3	20	17	0
Great Bay	C	10	4/19/19	10.7	20	76	21	0
Great Bay	C	11	4/19/19	7.2	30	68	19	0
Great Bay	C	12	4/19/19	19.9	40	104	18	0

Location	Transect	Quadrat #	Date	Biomass	Eelgrass % Cover	Shoot Density (#/m^2)	Canopy Height (cm)	ReproShoot (#/0.25m^2)
Great Bay	A	1	8/2/19	0.0	0	0		
Great Bay	A	2	8/2/19	0.0	0	0		
Great Bay	A	3	8/2/19	0.0	0	0		
Great Bay	A	4	8/2/19	0.0	0	0		
Great Bay	A	5	8/2/19	0.0	0	0		
Great Bay	A	6	8/2/19	0.0	0	0		
Great Bay	A	7	8/2/19	0.0	0	0		
Great Bay	A	8	8/2/19	0.0	0	0		
Great Bay	A	9	8/2/19	0.0	0	0		
Great Bay	A	10	8/2/19	0.0	0	0		
Great Bay	A	11	8/2/19	0.0	0	0		
Great Bay	A	12	8/2/19	0.0	0	0		
Great Bay	B	1	8/3/19	50.8	55	80	86	2
Great Bay	B	2	8/3/19	45.2	55	64	70	7
Great Bay	B	3	8/3/19	57.6	45	80	63	6
Great Bay	B	4	8/3/19	25.8	65	48	67	6
Great Bay	B	5	8/3/19	23.0	25	48	52	1
Great Bay	B	6	8/3/19	35.4	50	64	65	5
Great Bay	B	7	8/3/19	60.8	62	80	79	4
Great Bay	B	8	8/3/19	34.6	70	64	78	8
Great Bay	B	9	8/3/19	31.7	45	48	65	3
Great Bay	B	10	8/3/19	15.3	90	16	74	7
Great Bay	B	11	8/3/19	55.8	60	64	65	3
Great Bay	B	12	8/3/19	37.1	90	96	78	7
Great Bay	C	1	8/2/19	129.6	95	112	93	0
Great Bay	C	2	8/2/19	50.3	40	64	87	0
Great Bay	C	3	8/2/19	95.3	30	96	90	2
Great Bay	C	4	8/2/19	46.0	35	64	65	0
Great Bay	C	5	8/2/19	62.5	70	64	84	4
Great Bay	C	6	8/2/19	82.3	30	64	84	1
Great Bay	C	7	8/2/19	57.8	20	64	68	1
Great Bay	C	8	8/2/19	34.3	55	32	89	3
Great Bay	C	9	8/2/19	46.3	40	48	68	3
Great Bay	C	10	8/2/19	65.0	100	64	95	4
Great Bay	C	11	8/2/19	50.1	75	48	105	2
Great Bay	C	12	8/2/19	32.3	30	32	82	2

Location	Transect	Quadrat #	Date	Biomass	Eelgrass % Cover	Shoot Density (#/m^2)	Canopy Height (cm)	ReproShoot (#/0.25m^2)
Great Bay	A	1	10/29/19	0.0	0	0		0
Great Bay	A	2	10/29/19	0.0	0	0		0
Great Bay	A	3	10/29/19	0.0	0	0		0
Great Bay	A	4	10/29/19	0.0	0	0		0
Great Bay	A	5	10/29/19	0.0	0	0		0
Great Bay	A	6	10/29/19	0.0	0	0		0
Great Bay	A	7	10/29/19	0.0	0	0		0
Great Bay	A	8	10/29/19	0.0	0	0		0
Great Bay	A	9	10/29/19	0.0	0	0		0
Great Bay	A	10	10/29/19	0.0	0	0		0
Great Bay	A	11	10/29/19	0.0	0	0		0
Great Bay	A	12	10/29/19	0.0	0	0		0
Great Bay	B	1	10/28/19	no data	no data	0	no data	no data
Great Bay	B	2	10/28/19	no data	no data	0	no data	no data
Great Bay	B	3	10/28/19	2.7	45	28	no data	0
Great Bay	B	4	10/28/19	5.6	65	44	no data	0
Great Bay	B	5	10/28/19	2.1	40	20	no data	0
Great Bay	B	6	10/28/19	14.1	50	32	no data	0
Great Bay	B	7	10/28/19	4.1	60	32	no data	0
Great Bay	B	8	10/28/19	7.6	85	48	no data	0
Great Bay	B	9	10/28/19	5.1	94	52	63	0
Great Bay	B	10	10/28/19	3.5	70	36	59	1
Great Bay	B	11	10/28/19	8.3	64	48	53	1
Great Bay	B	12	10/28/19	12.8	40	32	63	1
Great Bay	C	1	10/29/19	7.6	97	92	82	0
Great Bay	C	2	10/29/19	13.7	99	68	85	0
Great Bay	C	3	10/29/19	13.2	98	92	84	0
Great Bay	C	4	10/29/19	5.5	97	44	69	0
Great Bay	C	5	10/29/19	26.2	95	80	75	1
Great Bay	C	6	10/29/19	6.5	98	48	79	0
Great Bay	C	7	10/29/19	10.4	95	96	98	0
Great Bay	C	8	10/29/19	8.7	95	68	103	0
Great Bay	C	9	10/29/19	5.7	99	76	97	0
Great Bay	C	10	10/29/19	9.4	99	96	97	0
Great Bay	C	11	10/29/19	13.6	99	64	94	0
Great Bay	C	12	10/29/19	4.1	99	44	93	0

Eelgrass data for biomass, percent cover, shoot density, canopy height and reproductive shoots at SeagrassNet site NH9.3, Transects A, B, and C at Fort Foster for July/August 2019 – October 2019.

Location	Transect	Quadrat #	Date	Biomass	Eelgrass % Cover	Shoot Density (#/m^2)	Canopy Height (cm)	ReproShoot (#/0.25m^2)
Fort Foster	A	1	7/25/19	no data	no data	no data	no data	no data
Fort Foster	A	2	7/25/19	0.2	5	8	27	0
Fort Foster	A	3	7/25/19	34.9	5	36	13	0
Fort Foster	A	4	7/25/19	12.3	20	80	78	0
Fort Foster	A	5	7/25/19	5.1	50	192	69	10
Fort Foster	A	6	7/25/19	13.1	1	4	11	0
Fort Foster	A	7	7/25/19	0.0	0	0		0
Fort Foster	A	8	7/25/19	2.9	2	20	35	0
Fort Foster	A	9	7/25/19	0.0	0	0		0
Fort Foster	A	10	7/25/19	6.9	5	8	55	0
Fort Foster	A	11	7/25/19	358.9	75	224	85	9
Fort Foster	A	12	7/25/19	8.4	4	28	28	0
Fort Foster	B	1	7/24/19	26.3	3	24		
Fort Foster	B	2	7/24/19	4.5	20	64		
Fort Foster	B	3	7/24/19	169.3	30	140	136	2
Fort Foster	B	4	7/24/19	0.0	5	0	24	0
Fort Foster	B	5	7/24/19	510.2	40	352	90	3
Fort Foster	B	6	7/24/19	254.0	25	144	73	8
Fort Foster	B	7	7/24/19	162.5	55	288	122	2
Fort Foster	B	8	7/24/19	332.3	47	352	77	4
Fort Foster	B	9	7/24/19	151.0	35	336	102	0
Fort Foster	B	10	7/24/19	93.6	50	128	119	3
Fort Foster	B	11	7/24/19	239.1	35	304	131	4
Fort Foster	B	12	7/24/19	242.5	60	160	107	2
Fort Foster	C	1	7/26/19	109.3	30	96	123	2
Fort Foster	C	2	7/26/19	51.9	50	128	123	2
Fort Foster	C	3	7/26/19	166.1	45	128	109	5
Fort Foster	C	4	7/26/19	156.3	55	192	130	1
Fort Foster	C	5	7/26/19	220.1	30	128	138	1
Fort Foster	C	6	7/26/19	158.4	60	160	95	3
Fort Foster	C	7	7/26/19	145.4	45	128	133	2
Fort Foster	C	8	7/26/19	88.1	45	96	141	3
Fort Foster	C	9	7/26/19	588.9	70	256	132	5
Fort Foster	C	10	7/26/19	320.4	70	224	141	2
Fort Foster	C	11	7/26/19	158.5	30	96	142	2
Fort Foster	C	12	7/26/19	101.8	70	160	109	4
Fort Foster	A	1	10/21/19	228.6	70	384	109	0
Fort Foster	A	2	10/21/19	0.0	0	0	0	0
Fort Foster	A	3	10/21/19	45.4	2	48	27	0
Fort Foster	A	4	10/21/19	27.1	30	96	53	0
Fort Foster	A	5	10/21/19	103.4	70	240	68	0
Fort Foster	A	6	10/21/19	0.0	0	0	0	0
Fort Foster	A	7	10/21/19	8.7	1	16	43	0
Fort Foster	A	8	10/21/19	109.3	25	208	34	0
Fort Foster	A	9	10/21/19	4.1	1	4	0	0
Fort Foster	A	10	10/21/19	12.9	10	52	54	0
Fort Foster	A	11	10/21/19	212.1	65	384	108	0
Fort Foster	A	12	10/21/19	69.6	25	128	64	0
Fort Foster	B	1	10/20/19	208.7	65	384	128	0
Fort Foster	B	2	10/20/19	207.7	50	352	141	0
Fort Foster	B	3	10/20/19	147.1	65	288	144	0
Fort Foster	B	4	10/20/19	0.0	3	16	28	0
Fort Foster	B	5	10/20/19	19.4	25	36	114	0
Fort Foster	B	6	10/20/19	249.9	70	400	136	0
Fort Foster	B	7	10/20/19	166.2	65	288	110	0
Fort Foster	B	8	10/20/19	202.7	45	224	127	0
Fort Foster	B	9	10/20/19	155.8	65	208	119	0
Fort Foster	B	10	10/20/19	163.9	40	288	123	0
Fort Foster	B	11	10/20/19	215.3	65	352	121	0
Fort Foster	B	12	10/20/19	197.0	30	304	100	0
Fort Foster	C	Fort Foster Transect C Not Sampled in October 2019						

Appendix 2

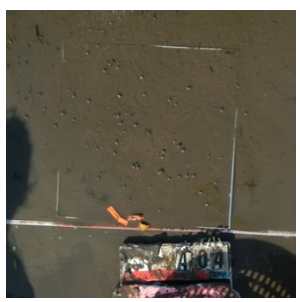
Photo mosaic of quadrat photos from the 3 SeagrassNet transects (A, B, and C) taken during April, July and October 2019 in Great Bay, New Hampshire and July and October 2019 at Fort Foster, Portsmouth Harbor. The photos are organized so that columns represent the month the photographs were taken while the rows show the 12 replicates along each of the three transects (A, B, and C) over two pages. Photos missing from Transect A in Great Bay are due to poor visibility. Other missing photos are due to sampling/camera difficulties.

Appendix 2, Site 9.2, Transect A, Quadrats 1-6

April 2019

No Photos

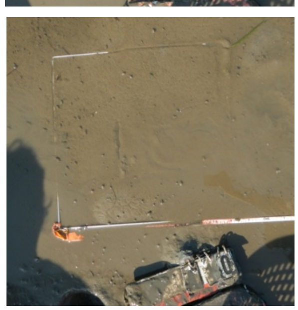
August 2019



October 2019

No Photos

Appendix 2, Site, 9.2, Transect A, Quadrats 7-12

April 2019	August 2019	October 2019
No Photos	   	**No Photos**

Appendix 2, Site 9.2, Transect B, Quadrats 1-6

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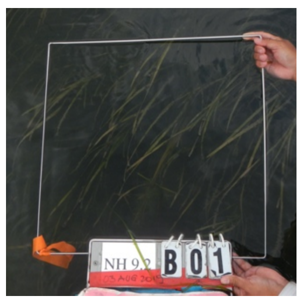
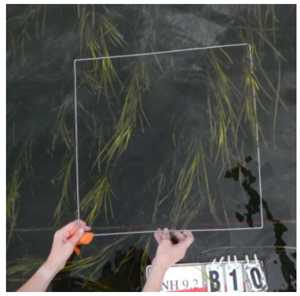
No Photos	  	**No Photos**

Appendix 2, Site 9.2, Transect B, Quadrats 7-12

April 2019	August 2019	October 2019
No Photos		
		


Appendix 2, Site 9.2, Transect C, Quadrats 1-6

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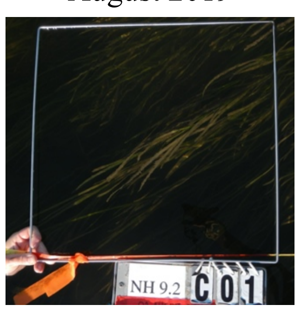
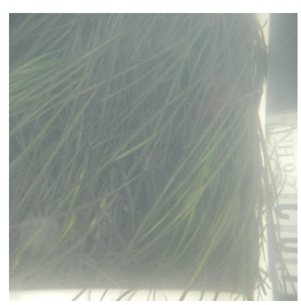
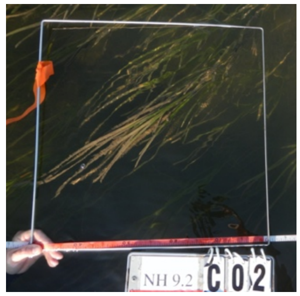
No Photos		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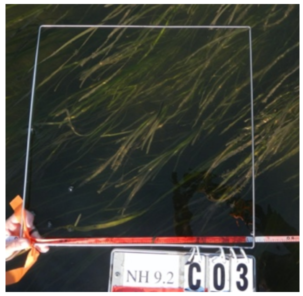
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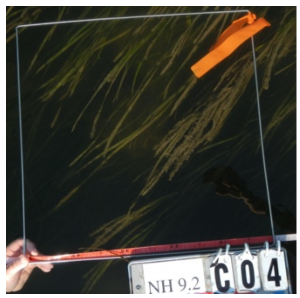
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NH 9.2
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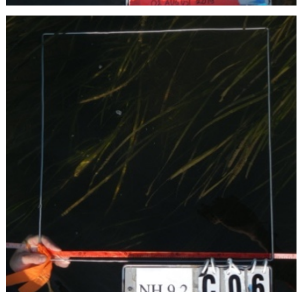
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Appendix 2, Site 9.2, Transect C, Quadrats 7-12

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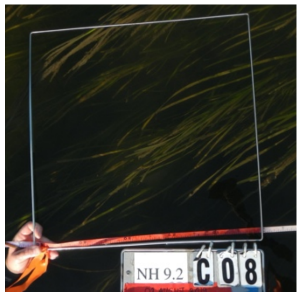
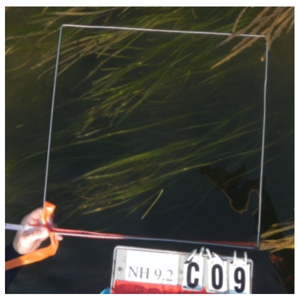
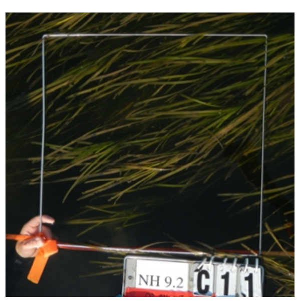
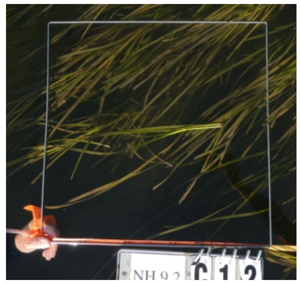
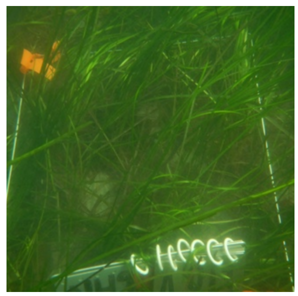
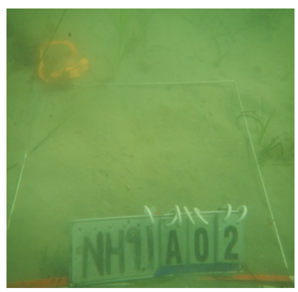
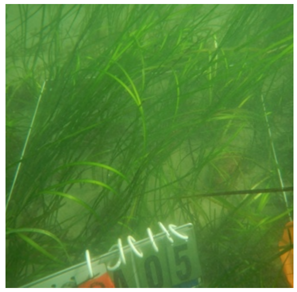
		
		
		
		

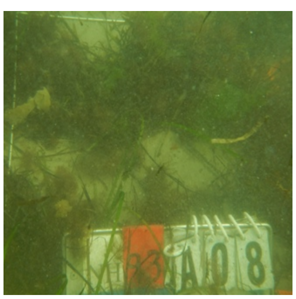
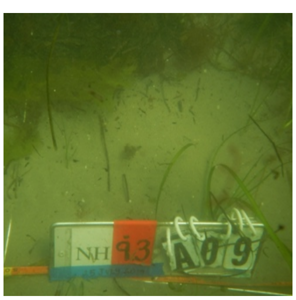


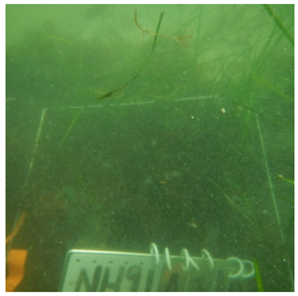
Appendix 2, Site 9.3, Transect A, Quadrats 1-6

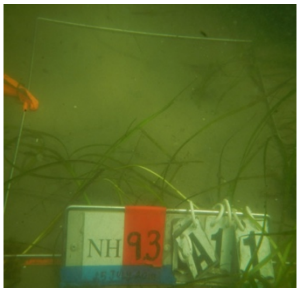
July 2019	October 2019
No Photos	   



Appendix 2, Site 9.3, Transect A, Quadrats 7-12

July 2019	October 2019
	
	
	

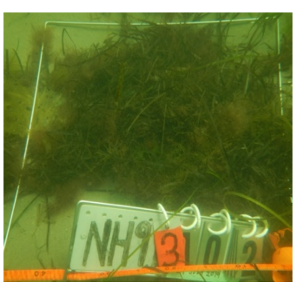


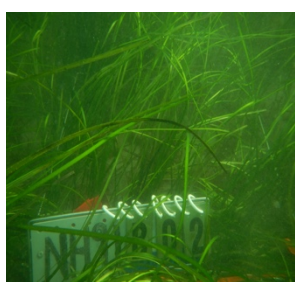


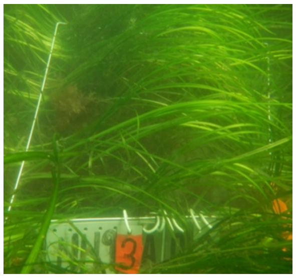
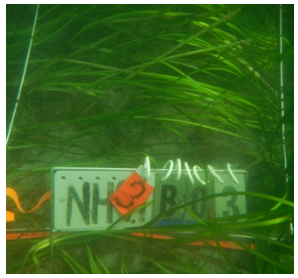
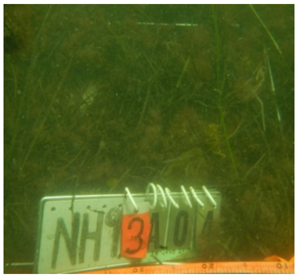
Appendix 2, Site 9.3, Transect B, Quadrats 1-6

July 2019 | October 2019

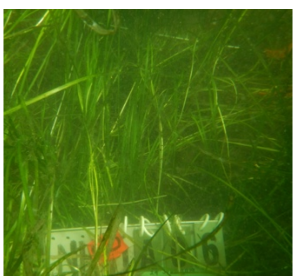
* Some July photos incorrectly labeled as 9.3A





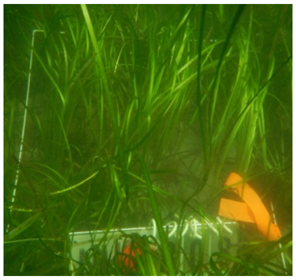




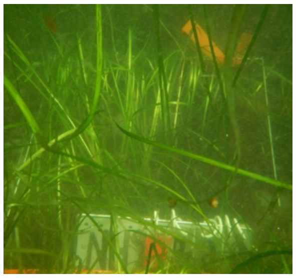

Appendix 2, Site 9.3, Transect B, Quadrats 7-12

July 2019

October 2019


NH 3 B08

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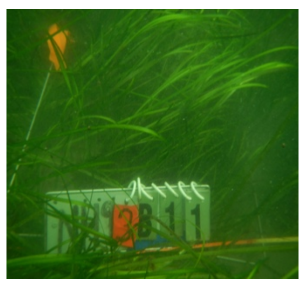
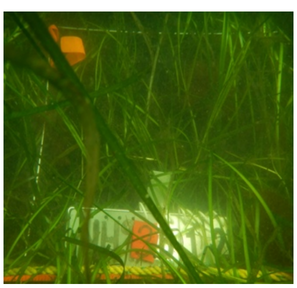
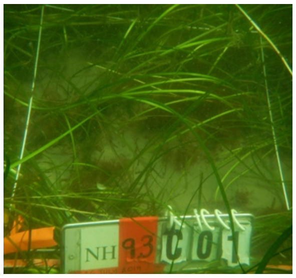
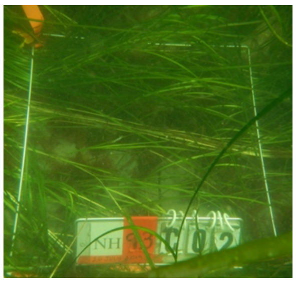
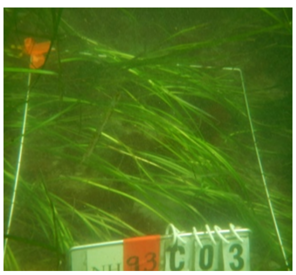
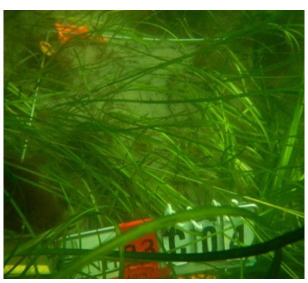
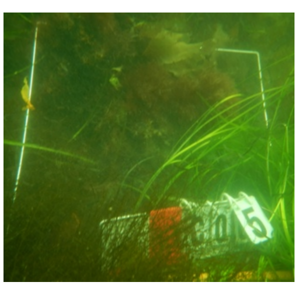
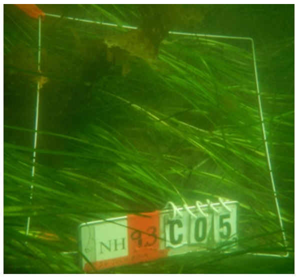

3 B11



Appendix 2, Site 9.3, Transect C, Quadrats 1-6

July 2019	October 2019
	**Not Sampled**
	
	
	
	

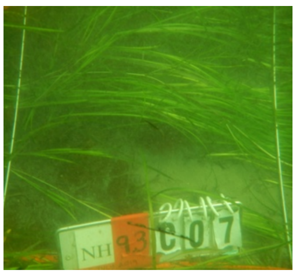


* Incorrectly labeled as C05;
should be labelled "C06"

Appendix 2, Site 9.3, Transect C, Quadrats 7-12

July 2019

October 2019



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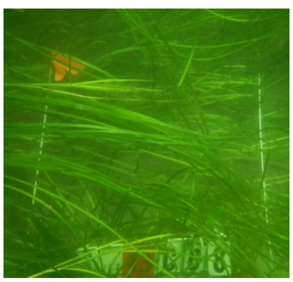

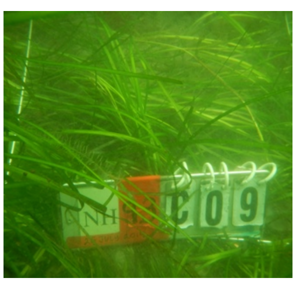

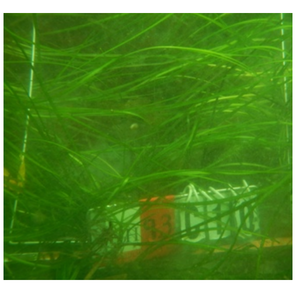

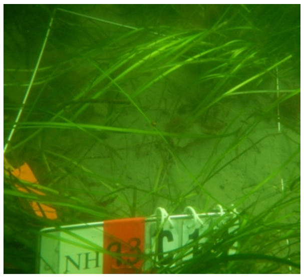
NH
C1


NH
C12

Appendix 3

QA/QC MEMORANDUM

To: Erik Beck, USEPA

From: Kalle Matso, PREP (Project QA Officer for SeagrassNet Monitoring)

Date: September 9, 2020

Re: Quality Assurance of 2019 SeagrassNet Monitoring Program

PURPOSE

The purpose of this memorandum is to document the results of quality assurance checks on the 2019 SeagrassNet monitoring program conducted by staff from UNH Jackson Estuarine Laboratory and PREP.

The project consisted of the continued monitoring and sampling of an established SeagrassNet site located in Great Bay, NH, as well as the establishment, monitoring, and sampling of a new SeagrassNet site located in Portsmouth Harbor at the site designated as "Fort Foster."

PREP reviewed these data with reference to the data quality objectives for the approved Quality Assurance Project Plan, available online: https://scholars.unh.edu/prep/420/

The following table contains assessments of the data quality objectives of the project. Supporting tables and figures are also provided below.

DATA QUALITY OBJECTIVE ASSESSMENTS

Data Quality Objective	Criteria	Protocol	Assessment of Criteria
Precision	Biomass measurements should be maintained to 1/100 of a gram.	Laboratory analysis will measure biomass with a Sartorius Balance (Type = E2000D).	All of the biomass measurements were maintained to 1/100 of a gram and were measured using a Sartorius Balance (Type = E2000D).
Bias	Percent cover, shoot density, canopy height, and grazing estimates should be comparable across members of the field assessment team within ±10%.	Field assessment team members will “calibrate” their assessments of percent cover, shoot density, canopy height, and grazing estimates prior to field work by reviewing published examples of visual representations of different percent covers (Short 2017). Field estimates will then be made by consensus of the field team. The field assessment team will also review photographs and associated percent cover estimates from previous years before the field season begins.	Field staff training included a “calibration” using published examples of visual representations of differe percent covers prior to data collection, as well as a revi of estimates to confirm a comparability across field sta members within ±10%. Field estimates were made by consensus of the field team. However, photographs anc associated percent cover estimates from previous years were not reviewed prior to the field season.
Spatial Accuracy	GPS units should have a reported accuracy less than or equal to 2 meters.	New transects will be established using a highly accurate, real-time kinematic (RTK) GPS. Transect locations will then be staked in the field using screw anchors. The minimum accuracy tolerance of the unit will be set to reject saving of waypoints with spatial accuracy less than 0.03m, thereby assuring spatial accuracy requirements are met or exceeded.	Field staff used GPS units that have a reported spatial accuracy of 3-5 meters under normal conditions. The Satellite Information screen was not used during field work, so the current spatial accuracy of the GPS units v not observed. Neither the Great Bay site nor the Portsmouth Harbor site were established using an RTK GPS. **This criterion and the method for georeferenc need to be reevaluated by PREP for future monitor**
Comparability	Field and laboratory data should be collected using standardized methods.	Check that protocols from the QAPP were used for field observations. The QA Manager should use filtering functions to check the field assessment team’s spreadsheets for data entry errors. All percent cover values should fall into one of the categories specified in the sampling methods. All biomass values should be between 0 and 500 grams. A minimum of 10% of field observations should be checked against electronic spreadsheets.	Field staff collected data using a standardized field dat sheet. The protocols in the QAPP were used for all fiel observations made (see Completeness below) except fo Shoot Density. In some cases, it was not clear which o two size quadrats was used for density counts. In those cases, counts were re-assessed and verified using photographs. Data entry errors were assessed and any anomalies were explainable when the field personnel v asked about the issue at hand.
Completeness	Field observations should be made for percent cover, shoot density, canopy height, grazing, and wasting disease estimates. In addition, environmental data collection should include light levels, temperature, and salinity.	Check field observations for completeness. Document reasons for any deviations from sampling protocol.	Field observations were made during sampling events percent cover, shoot density, and canopy height. Altho considered during eelgrass processing, wasting disease data were not captured during sampling events. Note th wasting disease is not requested on current field data sheets (**QAPP Appendix A**). Per environmental data criteria, light levels and temperature were collected via HOBO data loggers and salinity was ascertained from water samples.

Table 1: Field observations and environmental data collection performed.

Parameter Observed:	Completed	Pass or Fail
Percent Cover	Yes	Pass
Shoot Density	Yes	Pass
Canopy Height	Yes	Pass
Grazing	No	Pass
Wasting Disease	No	Fail
Light Levels	Yes	Pass
Temperature	Yes	Pass
Salinity	Yes	Pass